The Nuclear Cluster of the Milky Way

T.K. Fritz\textsuperscript{1,2}, S. Chatzopoulos\textsuperscript{1}, O. Pfuhl\textsuperscript{1}, O. Gerhard\textsuperscript{1}, S. Gillessen\textsuperscript{1}, R. Genzel\textsuperscript{1,3}, S. Tachella\textsuperscript{4}, F. Eisenhauer\textsuperscript{1}, T. Ott\textsuperscript{1}

VLT/NACOKs-band
87''=3.4 pc
box

Fritz et al
ApJ
submitted

Chatzopolus et al. in
prep.

Pfuhl et al.
741, 108

1: MPE
2: U of Virginia
3: UC Berkeley
4: ETH Zurich
Formation theories

• Local formation out of gas

• Globular clusters, migration to the center due to dynamic friction

• Semi local formation of large dense star clusters, migration to the center due to dynamic friction
Center of the Milky Way

Nuclear cluster within Nuclear disk (=Central Molecular Zone)


Spitzer/IRAC2, roughly extinction corrected

2.11°=300pc
Obtaining the overall properties of the old (>~50 Myrs) nuclear cluster of the Milky Way to clarify its origin

- Fritz et al. ApJ, submitted: Projected star density and flux far enough out to dissect the nuclear cluster from the nuclear disk and obtain its properties

Obtaining velocities in all three dimensions out to 4 pc

Use kinematics and density profile in spherical isotropic Jeans modeling

- Preview on early-type stars outside the central parsec
- Chatzopolous et al. in prep.: fit data with axisymmetric model

Starcount maps

Corrected for weak crowding

VISTA/VIRCAM  field of view 2000"
Archival data

HST/WFC-IR field of view 130"
Archival data
Starcount maps

VISTA/VIRCAM field of view 2000"

Raw map  extinction corrected

Dark clouds masked  dark clouds symmetrized

Archival data

Using the Fritz et al. 2011 extinction law

HST/WFC3/IR field of view 130"

extinction corrected

dark clouds masked  dark clouds symmetrized

Archival data
Nearly circular center, flattened further out

Exclusion of young stars important

Small flattening within 3 pc consistent with Schödel et al. 2007, A&A, 469, 125

Nuclear cluster ↔ nuclear disk   flattening bimodality?
Galfit: 2 Sersics

Nuclear cluster parameters:
\[ n = 1.42 \pm 0.03 \]
\[ R_e = 110 \pm 10'' = 4.4 \text{ pc}, \]
Flattening = 1.1 \pm 0.1

\[ L_{Ks} = (2.7 \pm 0.62) \times 10^7 \text{ L}_\odot; \text{ half the estimate, but within the errors of Launhardt et al. 2002, A&A, 384, 112} \]
The cluster is unusually bright Likely due to a high stellar mass density in the GC

Scd to Sm

Sa to Sbc
Spherical decomposition for the spherical symmetric Jeans modeling

Usage of flux and star density to estimate the uncertainty in the data

Two components (γ) necessary

Bright young stars outside the central parsec?

Bright young stars outside the central parsec?

Most early-type candidates of Nishiyama et al. 2013, A&A, 549, 57, are late-type


All stars of SINFONI data
Dynamical Data: 10000+ proper motions  
2500+ radial velocities

Using NACO (+MAD+Hokupa’a)  
Using SINFONI +250 Maser velocities
from Lindqvist et al 1992 and Deguchi et al 2004 further out
Rotation curve flattens at about 40″

McGinn et al 1989 data ○
Trippe et al 2008 data ■
Rieke et al 1988 data ●
CO bend head data ▲
Maser data △

Shows that Trippe et al 2008 selected probably the less suited data from McGinn et al 1989 (see also Schödel et al 2009)
Jeans model fitting

Extended mass:
- power law distribution
- constant M/L

Power law fitting obtains SMBH mass well below Ghez et al. 2008, Gillessen et al. 2009

\[ M_{\text{SMBH}} = (2.28 \pm 0.27) \times 10^6 M_\odot \text{, power law, all } R \]

\[ M_{\text{SMBH}} = 4.17 \times 10^6 M_\odot \text{, power law, 10'' < } R < 100'' \]

\[ M_{\text{SMBH}} = 4.17 \times 10^6 M_\odot \text{, M/L = const, 10'' < } R < 100'' \]
O(B)-stars: Bartko et al 2010
CND: Requena-Torres et al 2012,
large CND mass from Cristopher et al 2005
Sphere of influence: \( r_{\text{infl}} = 76.4 \pm 5.5'' = 3.03 \pm 0.25 \, \text{pc} \)

Cluster within 100
dotdot: \( M_{100''} = (6.11 \pm 0.52|_{\text{fix} R_0} \pm 0.97|_{R_0}) \times 10^6 M_\odot \)

Total cluster mass: \( M_{\text{NC}} = (13.08 \pm 2.51|_{\text{fix} R_0} \pm 2.08|_{R_0}) \times 10^6 M_\odot \)
Chatzopolous et al. in prep: Axisymmetric Flattened Models Explain Different Proper Motion and Line-of-sight Dispersions

Proper motion dispersion on major (l) and minor (b) axes
- Dynamic flattening ~ 1.4

Mean-square line-of-sight velocity;
The mass of the NSC within 100” ~ 4pc is ~ 7x10^6 M_{\text{solar}}
About 20% larger mass than in spherical modelling
Axisymmetric Flattened Models Explain Different Shapes of Proper Motion Histograms in $l$ and $b$

Angular bins

Near-circular bins on sky

Distribution of $\chi^2$ similar to expectations

Chatzopoulos et al. in prep.
I measure 0.5+/-.12, the axisymetric modeling leads to $M/L_{Ks}=0.6$.

From the star formation history $\rightarrow$ we calculate the expected $M/L$ (Both the $L$ measurement and the calculation excludes the 6 Myrs burst.)

$\rightarrow$ Salpeter: 1.1

$\rightarrow$ Chabrier: $M/L_{Ks}=0.7$

- M31 solar metallicity globulars old stars properties lead a total $M/L=0.3$

Globular cluster evolution in infall to GC

Shortly after formation
- Remnants
  - Giants
  - Low mass main sequence
  - Well mixed

Internal mass segregation
- Outer shell are lost in tidal field
- M/L first increases then decreases → not so good measure
- $L_{\text{diffuse}}/L$ decreases → good measure
Diffuse light


\[ H_{\text{diff}} / H = 27\% \pm 9\% \]

- Fits to normal IMF
- Excludes remnant dominated top heavy (I)MFs best
Summary and conclusions

• The central Galaxy light can be decomposed in two component, a inner nearly circular nuclear cluster and a nuclear disk. Transition at 100’’=4pc

• Sign for bimodality also in formation?: globular clusters → nuclear cluster, gas inflow from Galactic disk→nuclear disk

• The dynamics favor slightly higher flattening in the center.

• Most stars of the nuclear cluster are older than 5 Gyrs.

• M/L and L_diffuse/L make globular cluster origin less likely

• Why is the GC cluster brighter than most nuclear clusters? Is that connected to the existence of the likely bright nuclear disk? Then it is likely not formed by globulars.